

Review of Nevison et al. – round 2

I appreciate the thorough work of the authors: the quality of the manuscript is highly improved, and the results are clearer and the reading smoother. I have the feeling now that my problem with the ENSO discussion was the lack of a strong introduction and motivation.

However, a few of my comments were only partially answered or not discussed at all, and the revised version of the manuscript brought to the surface an issue concerning the discussion about the impact of the BDC. In addition, I have some minor/technical corrections that should be addressed.

I recommend publications after the points below are addressed.

Partially answered/unanswered comments.

In the following, I copy my comments of the previous review in italic.

- Conclusions. The authors highlight the relevance of airborne measurements for the current study in comparison with satellite data and that is a perfectly fair point. However, the authors do not provide any comments regarding the following possible points of discussion that I raised in the first review (pasted below). If the authors decide to disregard these suggestions, I would be interested to know why.
 - *The authors find that the surface N₂O growth rate presents hemispherical differences in the response to the impact from the QBO (strongest in the SH) and the BDC (strongest in the NH). Minganti et al., (2022) found hemispherical differences in the N₂O trends in the stratosphere (positive in the SH and negative in the NH) in satellite observations and reanalyses. I wonder if these hemispherical differences in the stratospheric trends can be related to the differences in the surface N₂O growth rate (or just mentioned).*
 - *It would be interesting to add one/two sentences on the possible impact of the solar activity on the N₂O growth rate. The major chemical destruction of N₂O occurs in the tropical upper stratosphere, so I do not expect large impact on the surface growth rate. However, some signal could still reach the troposphere and certainly an additional proxy for solar activity would help to better understand the N₂O changes in the stratosphere.*
 - *The authors could mention the possibility to perform sensitivity tests with GEOSCCM. For example, an experiment with the QBO switched off (if possible) would isolate the patterns due only to the BDC.*
- Results. I appreciate the compromise of the authors, but Figures 7 and 8 do not seem to meet this compromise (respectively, P19L421 and P20L439).
- *In Figure 8, the authors compare different observational datasets (Atom and ORCAS) for different periods (2016 and 2017). In my opinion, this makes the discussion difficult to follow. I suggest using only the ORCAS dataset for Figure 8. This would allow more room for discussion about the ORCAS dataset (maybe separating January and February?) and remove the asymmetry in Figure 8.*

Can the authors clarify on why this comment was not answered?

Discussion related to the BDC impact.

P1L32. “warm”. I think the “warm” here (and throughout the manuscript) arises from some confusion. The N₂O-poor stratospheric air that is transported by the BDC over that region is not necessarily warm. The downwelling (i.e., the downward transport) due to the BDC at high

latitudes during winter warms up the lower stratosphere because it's a diabatic process. Because of that, the PLST is used as a proxy of the strength of the BDC, i.e., warmer PLST indicate stronger downwelling due to stronger BDC.

In a nutshell, the BDC does not bring "warm air" to the lower stratospheric high latitudes, the air over that region is warm because of the BDC (e.g., Holton et al., 1995).

This comment does not change the conclusions of the authors: warmer PLST indeed indicate stronger BDC, but I suggest removing the "warm" before "N₂O-poor air" throughout the manuscript as it might generate confusion.

Minor/technical comments.

- P1L15. Izana -> Izaña.
- P1L24. I suggest removing "atmospheric".
- P1L32. circulation -> Circulation (throughout the manuscript).
- P2L42. I suggest removing "(GWP)" as the abbreviation is not used further in the manuscript.
- P2L50. I suggest changing "ppb" with "ppbv" throughout the manuscript.
- P2L52. N is not defined here, but it is defined at the line below (L53). I suggest moving "nitrogen (N)" to L52.
- P3L61-65. "While larger ... (Nevison et al., 2018)." I suggest re-phrasing this long sentence into two sentences separated by a period.
- P3L75-76. "... phases in the eastern tropical Pacific (ETP.)". I suggest being more specific here and mention sea surface temperature – something like: "... phases in sea temperatures over the eastern tropical Pacific (ETP)".
- P3L82. "northern hemisphere" and "southern hemisphere" are already defined.
- P4L90. I suggest changing "dynamics" with "dynamical processes".
- P4L113. "altitude-latitude cross sections" I suggest specifying that you are talking about measurements here.
- P5L130-131. "with the premise of causation". This sentence belongs more to the Methods section. Also, could you provide your reasoning (or some reference) regarding why correlation is evidence of causation for this case?
- P6L154. I suggest swapping "116+-2" with "119+-2" since the authors highlight that the lifetime is decreasing after 2000.
- P6L158. "they". Do the authors refer to the QBO and temperature here? If yes, could they specify it?
- P6L166. (HATS) (Thompson et al., 2004) -> (HATS, Thompson et al., 2004).
- P6L167. (CCGG) (Lan et al., 2022) -> (CCGG, Lan et al., 2022)
- P7L174. Is the "X2006A" necessary here? It sounds strange to someone not familiar with this terminology like me.
- P7L182. Is 13 a subset of the ~55 sites mentioned before? If yes, could the authors specify it?
- P8L211. "HIPPO" not yet defined here.
- P8L219. "HIAPER" not yet defined here.
- P8L223. "ORCAS" not yet defined here.
- Section 2.3.2. This section contains only one paragraph and I suggest merging it with Section 2.3.1 to retain only Section 2.3.
- P10L265. PLST is already defined here.
- P10L269-270 "PLST reflects (Holton, 2004)". This sentence belongs more to the Introduction where the authors first talk about the PLST.
- P11L295. "0.4 degrees C" -> "0.4 degrees °C".

- Figure 1 caption. I suggest changing “...atmospheric N2O modeled...” with “... N2O mixing ratios [ppbv] modeled ...”. For the captions of Figures 2, 3 and 4, I suggest something like “Anomalies of N2O mixing ratios [ppbv]”.
- P15L364. I suggest adding “in the NH” after “altitude-latitude contours”.
- Figure 5 caption. “... pressure-latitude contour plots arranged to form”. I suggest re-phrasing with something like “... pressure-latitude contours of anomalies of N2O mixing ratios [ppbv] to form”.
- P17L393-394. Given that the manuscript has shortened and become clearer, I would remove the additional definition of PLST here.
- P17L395. I suggest adding “(Section 2)” after “Methods”.
- P17L397. Again, why do the authors assume that significant correlation between N2O AGR and one index implies causal influence of that index on the N2O AGR?
- Figure 6. I suggest swapping panels 6b and 6c. This way, the discussion can focus on the QBO first and then on the PLST (i.e., first discuss 6a and 6b, then 6c and 6d).
- Figure 6 caption. Can the authors specify the units of the AGR in the caption?
- P19L421. I suggest introducing Figure 7 as was done for the previous figures.
- Figure 7. I suggest re-arranging the discussion of Figure 7 so it would smoothly describe 7a, 7b, 7c and 7d. In alternative, the authors could keep the discussion as it is and re-arrange the panels in Figure 7 accordingly (panels *a* and *b* for temperature and *c* and *d* for QBO). I find the current discussion of Figure 7 (7b, 7d, 7a, 7c) rather counter-intuitive.
- Figures 7 and 8 captions. As for Figure 6, I suggest specifying the units of the AGR in the caption.
- P20L439. Also here, I suggest introducing Figure 8 as for the previous figures.
- P20L440. I suggest re-phrasing “...with little to no ...”.
- P21L450. I suggest re-phrasing “... of the seasonal cycle NOAA sites.” with “... of the seasonal cycle for NOAA sites at remote mid and high latitude.”
- P22L458. “January”. Why do the authors mention January if panel 9b and its caption say February?
- P22L464. Similarly to the comment above, why do the authors mention March if panels 9c,d and their captions say February?
- Figure 9 caption. I suggest re-phrasing “a) ... mean seasonal cycle in N2O ...” with “a) ... mean seasonal cycles in N2O mixing ratios [ppbv] for the NOAA surface station observations (Obs), and the GEOSCCM total N2O (N2O_{tot}) and stratospheric N2O (N2O_{st}) ...”. Also, I suggest re-phrasing “b) NOAA surface N2O seasonal anomalies ... ” with “b) NOAA surface seasonal anomalies of N2O mixing ratios [ppbv]”. I also suggest a similar re-phrasing for “Bottom row shows seasonal anomalies for” with “Bottom row shows seasonal anomalies of N2O mixing ratios [ppbv] for ...”.
- P23L476. The authors mention “February” but the ORCAS dataset also covers January.
- Figure 10 caption. I suggest changing “N2O anomalies in ppb” with “Anomalies of N2O mixing ratios [ppbv]”.
- P24L490-494. I feel that this paragraph gives too much importance to a figure that is not shown in the main manuscript. I suggest reducing this paragraph to a sentence that captures its essence.
- P25L500. I suggest replacing “shows up” with “enters”.
- P25L512. I suggest re-phrasing “...simulates too long a delay ...” with “... simulates a too long delay”.
- P25L513. “The rate of descent”. Can the authors specify what is descending?

- P25L517. "... may be overestimated" why do the authors think that the summer soil emission might be overestimated? Was that a conclusion of Liang et al., 2022?
- P26L534. Given my comment above about the warming due to the BDC, I suggest removing "warm".
- P26L539-540. I suggest moving the reference to Ray et al. 2020 at the end of the sentence and put it between parentheses (Ray et al., 2020).
- P27L562. "Paradoxically". Why do they authors say that? Did they expect something different?
- Section 4.2. Very interesting section. However, I think it can be summarized and merged with Section 4.1 to highlight their main points. When doing that, I suggest clearly separating the discussion between the SH and NH (you could even have a subsection for the SH and one for the NH).
- P28L589. I suggest removing "ENSO".
- P29L611. I suggest re-phrasing "tease out".
- All figures. Please replace the occurrences of "ppb" with "ppbv".